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A STUDY OF DISEASE RESISTANCE AND OTHER VARIETAL CHARACTERS OF WHEAT—APPLICATION OF THE ANALYSIS OF VARIANCE, AND CORRELATION.*

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INTRODUCTION

The essential problem in variety testing is the determination of inherent differences between the varietal units. If the measurable effects of these inherent differences are large as compared with the differences due to experimental error the test is a very efficient one, but if the converse is true the test is of little value. Thus the efficiency of the test depends upon the relative proportions of the two variances, the one due to inherent differences between the varieties, and the other to random variation within the test commonly referred to as experimental error.

On this basis the analysis of variance as developed by Fisher (*1*)‡ may be used to furnish valuable information as to the nature of a particular variety test. It enables us to determine the significance of the difference between the variance of the variety means and the variance due to experimental error. Then if we can assume with a reasonable degree of certainty that inherent varietal differences exist, we can measure the efficiency of the test; under these circumstances if the test is efficient, the varietal variance will be significantly greater than that due to experimental error. Also, we can use the same analysis to detect the presence of varietal differences. The varietal variance will be significantly greater than the variance due to experimental error only when there are real inherent differences between the varieties.

The value of an analysis of this kind became evident to the writers in examining, during the season of 1928, two groups of strains in the rod rows which were heavily infected with black chaff. One of these groups consisted of 86 strains from an H-44-24 × Marquis cross. In this cross the inheritance of resistance to black stem rust has been described (Goulden, Neatby and Welsh (*3*)), with special reference to the inheritance of a mature plant type of resistance which is governed apparently by a single pair of factors. The 86 strains tested in the rod rows for the first time in 1928 all possessed the mature plant type of resistance to rust which they inherited from the H-44-24 parent. This parent is susceptible to black chaff and since the hybrid strains in 1928 were severely affected it seemed possible that a close or perhaps a complete linkage might exist between the factors for susceptibility to black chaff, and rust resistance. The strains were uniformly rust resistant as far as could be determined from a test conducted in another part of the field in which a severe epidemic was produced artificially, and complete linkage of the two characters would therefore mean uniform sus-

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‡Reference by number to literature cited.

ceptibility to the bacterial disease. The latter varied a great deal from plot to plot so that although some strains were relatively free, it was impossible to determine from observation whether or not real inherent differences between the strains existed. It was here that the analysis of variance appeared useful, as the demonstration of significant varietal differences for susceptibility to black chaff would indicate incompleteness in the linkage with rust resistance. Selection of the strains least affected by black chaff would then be of real value.

The other group of strains consisted of 46 pure lines of Marquillo. These were even more severely affected by black chaff than the H-44-24 × Marquis lines and the analysis of variance was again applied in order to determine whether or not selection would be of any value. The parent stock of Marquillo from which the selections were made was somewhat mixed so that many of the selected lines showed considerable variation from the parental type.

The value of the analysis of variance in the determination of the significance of varietal differences depends upon the efficiency of the test. When the experimental error is large as in a test in which there are an insufficient number of replications, the demonstration of varietal differences is more difficult, i.e., the differences cannot be demonstrated unless they are quite large. In our rod row test of the above mentioned groups of strains there were only three replicates, so that the experimental error was relatively large and varietal differences could not be demonstrated unless they were proportionately great. Also in order to supply a background for the reliability of the method of analysis for a particular case, the data for several other characters including yield, strength of straw, and earliness, obtained from the rod row tests of 1925 and 1926, were subjected to the same type of analysis.

The Analysis of Variance

A complete discussion of the analysis of variance is given by Dr. R. A. Fisher in "Statistical Methods for Research Workers." From the standpoint of the ordinary field plot test the following equation is fundamental:

$$\sigma_T^2 = \sigma_V^2 + \sigma_R^2 + \sigma_E^2 \qquad (1)$$

Where σ_T^2 = total variance.
σ_V^2 = variance of the means of varieties.
σ_R^2 = variance of the means of replicates.
σ_E^2 = variance within replicates and which may be considered experimental error.

Expressing each variance in terms of the sums of squares of the deviations from the respective means, equation (1) becomes—

$$\frac{S\,(x-\bar{x})^2}{k\,n'} = \frac{S\,(\bar{x}_V-\bar{x})^2}{n'} + \frac{S\,(\bar{x}_R-\bar{x})^2}{k} + \frac{S\,(x-\bar{x}_V)^2}{k\,n'} \qquad (2)$$

Where x = yield of any one plot.
$\bar{x}$ = general mean.
$\bar{x}_V$ = mean yield of any one variety.
$\bar{x}_R$ = mean yield of any one replicate.
k = number of replicates.
n' = number of varieties.

Expressing (2) in terms of the sums of squares only, we have—

$$S(x-\bar{x})^2 = kS(\bar{x}_V-\bar{x})^2 + n'S(\bar{x}_R-\bar{x})^2 + S(x-\bar{x}_V)^2 \quad (3)$$

In this equation the total sum of squares and the first and second term on the right can be calculated directly from the data. The last term on the right can then be equated from the other values.

Having obtained the sums of squares as in equation (3) each sum of squares is converted into a variance by dividing by the degrees of freedom. The significance of the difference between any two variances can then be determined by the test developed by Dr. Fisher. This test involves the transformation of the difference into a statistic known as z which is normally distributed and its significance can be tested by means of its standard deviation.

For testing the significance of the difference between the variance of the varieties and the variance within replicates z is given by—

$$\tfrac{1}{2}\left\{\log_e \frac{kS(\bar{x}_V-\bar{x})^2}{n'-1} - \log_e \frac{S(x-\bar{x}_V)^2}{n'(k-1)}\right\}$$

and the standard deviation of z by—

$$\sqrt{\tfrac{1}{2}\left(\frac{1}{n'-1} + \frac{1}{n'(k-1)}\right)}$$

In the actual calculation of z it should be noted that natural logarithms must be used and that the most convenient method is to obtain the difference between the logarithms of the *square roots* of the two variances.

The method will be demonstrated by using yield data from the 1926 rod rows. These data are set forth in table 1 in the form of frequency distributions for the yields of each replicate and for all of the plots taken together. Note that the actual class interval which is 16 grams in this case is replaced by a class interval of one. This interval is adhered to throughout the calculations. From table 1 we calculate the means of the replicates and the total sum of squares. In table 2 are given the means of the replicates and the frequency distribution of the variety means. From these two we calculate the respective sums of squares and then proceed as in table 3 to the final analysis of the results. We find that the value of z is 2.34 times its standard deviation and conclude that the variance of the varieties is significantly greater than that due to experimental error. This can be taken also as a fair measure of the efficiency of the test as the 156 varieties tested were a heterogeneous group among which there was undoubtedly a considerable amount of variation in inherent yielding capacity.

TABLE 1. *Yield data from 1926 wheat rod rows given as frequency distributions by replicates and for all plots.*

Class Values	Rep'l I	Rep'l II	Rep'l III	Rep'l IV	Rep'l V	Total
1					1	1
2					2	2
3				2	2	4
4			4	2	1	7
5			1	1	4	6
6		4	9	3	5	21
7	1	8	7	3	4	23
8	3	8	15	9	6	41
9	4	6	18	12	9	49
10	1	3	13	6	11	34
11	1	12	7	9	13	42
12	8	16	17	15	4	60
13	9	18	6	14	12	59
14	3	12	11	16	10	52
15	9	6	7	12	15	49
16	12	11	7	6	8	44
17	12	7	8	6	14	47
18	11	10	5	3	7	36
19	23	6	4	11	6	50
20	11	5	5	7	6	34
21	12	5	3	7	3	30
22	11	1	3	2	5	22
23	8	6	2	1		19
24	4	6	2	3	3	18
25	5	2		2	2	11
26		1	1	2		4
27	2	1		2		5
28	3		1			4
29						
30	2					2
31		2				2
32	1					1
33					1	1
Totals	156	156	156	156	156	780

TABLE 2. *Frequency distribution of variety means for yields of 1926 wheat rod rows, and means of replicates.*

VARIETY MEANS		REPLICATE MEANS		
Class Values	Freq.			
1	2	Repl.	I	18.3205
2	3		II	14.7885
3	10		III	12.4679
4	18		IV	14.1410
5	19		V	13.5320
6	24			
7	23			
8	19			
9	17			
10	10			
11	4			
12	5			
13	1			
14				
15	1			
	156			

TABLE 3. *Analysis of variance—yield data from 1926 wheat rod rows.*

Variance of	Sum of squares	Degrees of Freedom	Variance	Standard Deviation	Loge
Replicates	3081.84	4			
Varieties	5110.10	155	32.97	5.742	1.7478
Remainder	15180.21	620	24.48	4.948	1.5990
Total	23372.15	779			Diff. = .1488=z

$$\sigma_z = \sqrt{\tfrac{1}{2}\left(\frac{1}{155} + \frac{1}{620}\right)} = .0635$$

$$z/\sigma_z = \frac{.1488}{.0635} = 2.34$$

CORRELATION

In order to complete the study of the characteristics of the two groups of strains mentioned above, zero order and partial correlation coefficients were calculated for all possible pairs of the variables measured. This type of analysis determines the degree of association between pairs of characters for the material studied and is especially valuable in demonstrating the effect of disease upon yield.

Within the H-44-24 × Marquis group an additional study was made of the relation between awning and the other characters mentioned. The procedure consisted of drawing up contingency tables in which the distribution for any one character such as yield was compared in the awned and awnless classes.

The data from the 1925 rod rows were analysed and reported on previously by Goulden and Elders (*2*). It was found that stem rust and leaf rust were both negatively correlated with yield. In a similar study Hayes, Aamodt and Stevenson (*5*), obtained significant correlations between stem rust and yield and leaf rust and yield, and also between black chaff and yield. Using data from rod rows of oats Immer and Stevenson (*6*) demonstrated that crown rust in addition to other characters was closely associated with yield.

BLACK CHAFF

The principal object of this study was to obtain information relative to two groups of strains which were severely affected by a disease we have called black chaff. This disease has not been positively identified as the black chaff disease caused by *Bacterium transluscens var. unduloscum,* Smith, Jones and Reddy, and described by Smith (*7*), but it resembles black chaff very closely as the following description will show.

Infection was first observed in the cereal breeding nursery at Winnipeg in 1926; it was found only on the variety H-24-44 and its hybrids with Marquis. The infections were characterized by dark brown lesions more or less striated, extending down from the last node.

In 1927 the cereal breeding nursery was located at Morden, Manitoba. The disease appeared again and infection was much greater than in the previous year. The lesioning extended over the entire plant appearing first

just below the last node and later over the neck and head. Head and neck infections however, were patchy and rarely if ever continuous, as were lesions below the node. Besides the H-44-24 × Marquis hybrids, Kota and Pentad were also attacked.

In 1928 infection was still more severe, and practically all varieties and strains in the Winnipeg nursery were attacked in some degree. The effect on some varieties is quite different from that described for H-44-24 and the H-44-24 × Marquis hybrids. When visiting the nursery in August 1928, Dr. J. J. Christensen of the University of Minnesota observed that infected plants of the variety Marquillo were characterized by a scale of bacterial exudate over all infected parts of the plant. On most other varieties the presence of exudate could not be detected. The general appearance of the disease of Marquillo also differed from that of H-44-24, Kota, etc. The lesioning so characteristic of H-44-24 is absent; the discoloration being uniform, less intense, and usually extending over the entire culm and head. In an F_3 population of H-44-24 × Marquillo, the two types were very clearly segregated, only in a few cases were plants observed with both types of infection. In 1927 Marquillo strains growing adjacent to infected H-44-24 × Marquis were conspicuously free from disease. It is therefore open to question as to whether these two diseases are caused by the same organism.

Black chaff data in this study were estimated on a percentage basis. In the case of H-44-24 × Marquis strains a separate note was taken on heads, necks, and the region just below the last node. The estimates of infection on different portions of the plant were found to be closely correlated and on this basis they were combined in a mean value for the whole plant. On the Marquillo strains infection was very uniform for all parts of the plant so that one note only was taken.

Results and Discussion

1. *Analysis of Variance.*

The results of the analysis of variance are given in table 4 in the form of values of z divided by its standard deviation. When this value is 2 or more it indicates that the variance of the variety means is significantly greater than the variance within replicates, and we can take this to mean that actual differences between the varieties exist. It is evident from the table that such a value will vary from year to year depending on the efficiency of the test relative to the difference to be determined. Thus in 1925 considering yield we obtain a z/σ_z of 13.2, while in 1926 with practically the same group of varieties it is only 2.3. This is a logical result when we know the complete circumstances. A very heavy stem rust epidemic occurred in 1925 and affected the yields of the varieties according to their susceptibility. A great variation in susceptibility to rust resulted in a great variation in yield, the effect of rust almost completely obscuring the random error due to soil variation. In 1926 the effect of rust was negligible while soil variation was probably greater than for average seasons. The varieties therefore tended to yield more alike in proportion to the experimental error and this is reflected in the lower value of z/σ_z. This result demonstrates

also that a significant value of z gives evidence of the existence of varietal differences only in relation to the conditions of the test. Under a peculiar set of circumstances the group of varieties tested in 1925 and 1926 which undoubtedly possess real differences with respect to yielding capacity might give an insignificant value of z for the comparison of varietal variance with variance within replicates. It is obvious however that such circumstances would be rare. On the other hand a significant value of z cannot be obtained when real differences do not exist unless there is some systematic error in the planning of the test.

Again considering the yield results we note that z is significant for all varieties and for the H-44-24 × Marquis strains, while it is not quite significant for the Marquillo strains. The latter result appears somewhat paradoxical when we note, as shown in table 6, that there is a significant correlation between black chaff and yield, and from table 4 again that z is significant for black chaff. This is probably explainable on the basis that yield responds more readily to soil differences than does black chaff with the result that the differences are harder to detect. In a more extensively replicated plot test it is probable that the value of z for yield would be more significant.

Earliness was measured in two ways, as days from seeding to heading and as days from seeding to ripening. A comparison of these two methods of estimating earliness is possible from the values of z/σ_z for 1925 and 1926. In both cases z is highly significant but slightly more so when earliness is taken as days from seeding to heading.

For the H-44-24 × Marquis strains z for earliness is quite significant. While there is only a few days difference between the heading dates of the two parents, it was evident from observation of the strains that real difference existed. The Marquillo strains appeared more uniform for earliness and z/σ_z is lower than for the other group.

It is interesting to note the difference between the values of z/σ_z for height and strength of straw. The former are negative but quite insignificant while the latter are positive and significant. There are probably no significant height differences between the strains in both groups but height obviously varies considerably with soil differences and if such differences are present a much more extensively replicated test would be necessary in order to detect them with a reasonable degree of accuracy. Strength of straw appears, as would be expected, to be much less subject to variation with soil conditions. In 1925 two replications were quite sufficient to bring out the differences between the varieties.

In 1925 when a heavy stem and leaf rust epidemic occurred it was very easy to distinguish varying degrees of resistance among the varieties. It was evident in reading rust percentages on different plots of the same variety that the greatest source of error was in the estimation. In other words the actual random variation appeared quite small. It was observed however that there was a high correlation between the rust estimates for the two replicates and the two readings were therefore considered to be

sufficient. For the two replicates the values of z/σ_z for the estimates of stem and leaf rust are 10.5 and 11.5 respectively. This again demonstrates that the test on two replicates was quite sufficient.

The results of the analyses for black chaff are given in the lower part of table 4; z is quite significant in each case if we place the level of significance at $z/\sigma_z = 2$. This seems quite justifiable from the standpoint of general statistical procedure and also from the standpoint of the other values reported in table 4. Thus it seems reasonable to assume that real differences in the yielding capacity of the H-44-24 × Marquis strains exist, and the value of z/σ_z is 2.1. Also in 1926 a very heterogeneous group of varieties were tested and the value of z/σ_z is 2.3. The basis is sound therefore for concluding that there are real inherent differences for resistance to black chaff among both groups of strains. This is decidedly a valuable conclusion as it means not only that progress can be made in the selection of the most desirable of these strains but that progress can be expected in any other group of strains of similar parentage which are brought forward to the rod row test. If a linkage exists between mature plant resistance to stem rust and susceptibility to black chaff in the H-44-24 × Marquis cross it is evidently incomplete, and by growing large enough hybrid populations it should be possible to eliminate susceptibility to black chaff almost completely.

TABLE 4. *Values of z/σ_z for the analysis of eight varietal characters of wheat from results of rod row tests, 1925, 1926, and 1928.*

Character	1925 varieties	1926 varieties	1928 strains H-44-24	1928 strains Marquillo	1928 all varieties
Yield	13.2	2.3	2.1	1.8	3.2
Earliness (days to heading)	29.3	22.2	4.1	2.2	—
Earliness (days to mature)	26.2	16.5	—	—	—
Height	—	—	–0.11	–0.48	—
Strength of straw	(10.8)	17.1	4.1	4.7	—
Percentage Stem Rust	(10.5)	—	—	—	—
Percentage Leaf Rust	(11.5)	—	—	—	—
Percentage Black Chaff—					
Base	—	—	3.2	—	—
Culms	—	—	3.1	—	—
Heads	—	—	2.2	—	—
Mean	—	—	3.9	3.8	—

Note—Figures in parenthesis calculated from two replicates only.
The remainder for 1925 are calculated from four replicates.

2. *Correlations*

For the two groups of strains zero order and partial correlation coefficients have been calculated for the relations between earliness, height, black chaff, strength of straw, seed weight, and yield. These are given in tables 5 and 6. The symbols used to represent the different characters are as follows:

Y = yield
B = black chaff
E = earliness (days from seeding to heading)
S = strength of straw
H = height
W = weight of 500 kernels

Note also that "Student's" distribution of t has been used in order to determine the significance of the coefficients. The formulae given by Fisher (*1*) were used to calculate the values of t; these are—

$$t = \frac{r}{\sqrt{1-r^2}}\sqrt{n'-2}$$ for zero order coefficients

$$t = \frac{r}{\sqrt{1-r^2}}\sqrt{n'-2-v}$$ for partial coefficients where v is the number of variables eliminated.

If the value of t for any coefficient is 2 or more, the coefficient may be considered significant. In tables 5 and 6 we have given only those values of t that are 2 or more.

The correlation coefficients of most interest are those between yield and the other five variables. Note that those of zero order are all quite significant for both groups of strains. Considering the partial coefficients: in the Marquillo strains, yield is significantly correlated with black chaff, seed weight, and height; in the hybrid strains yield is significantly correlated with black chaff, seed weight, height, and earliness.

The correlations between black chaff and yield were quite to be expected considering the obvious effect of the disease on the general condition of the plants. This result demonstrates the economic value of resistance to black chaff if the disease should become epidemic.

The relation between yield and height is evidently a reflection of high yielding ability in its association with general vigour of the plants. Black chaff which is negatively associated with height as determined from the zero order coefficients evidently does not account for all of the relation between yield and height as the partial coefficients $r_{YH \cdot BESW}$ are both high.

Between yield and seed weight the partial correlation coefficients are slightly lower than those of zero order but still quite significant. The effect of black chaff is probably responsible for this difference.

For yield and strength of straw the correlations are quite interesting. This relation is significantly negative as determined by the coefficients of zero order but the partial coefficients are very low. This result is evidently due to the actual correlations between yield and height, and strength of straw and height. For the Marquillo strains we note that $r_{YH \cdot BESW} = .4744$ and $r_{SH \cdot YBEW} = -.5380$. As the yield increases we have greater height and a

TABLE 5. *Correlation coefficients for characters of H-44-24 × Marquis strains.*

Characters	Zero order Coefficients	t	Characters	Partial Coefficients	t
YE	–.3790	3.66	YE.BSHW	–.4530	4.42
YH	.6147	6.97	YH.BESW	.4996	5.03
YB	–.4991	5.15	YB.ESHW	–.2562	2.31
YS	–.2477	2.99	YS.BEHW	.0813	
YW	.4991	5.15	YW.BESH	.2632	2.38
BE	.2770	2.58	BE.YSHW	.1513	
BH	–.3534	3.38	BH.YESW	–.1236	
BS	.1401		BS.YEHW	–.0402	
BW	–.2475	2.28	BW.YESH	.0185	
ES	.0322		ES.YBHW	.1420	
EH	.0492		EH.YBSW	.3984	3.79
EW	–.0943		EW.YBSH	.0092	
SH	–.5189	5.43	SH.YBEW	–.5224	5.34
SW	–.0395		SW.YBEH	.2257	2.02
HW	.4446	4.44	HW.YBES	.2591	2.34

Multiple corelation $R_{Y\cdot BESHW} = .7853$

TABLE 6. *Correlation coefficients for characters of Marquillo strains.*

Characters	Zero order Coefficients	t	Characters	Partial Coefficients	t
YE	–.4894	3.72	YE.BSHW	–.2920	
YH	.5718	4.62	YH.BESW	.4744	3.41
YB	–.5352	4.20	YB.ESHW	–.4556	3.24
YS	–.5799	4.72	YS.BEHW	.1637	
YW	.6197	5.24	YW.BESH	.5308	3.96
BE	.0915		BE.YSHW	–.3216	2.14
BH	–.3500	2.48	BH.YESW	.2877	
BS	.6458	5.61	BS.YEHW	.5924	4.15
BW	–.2393		BW.YESH	.1959	
ES	.3831	2.75	ES.YBHW	.2699	
EH	–.2948	2.05	EH.YBSW	.0724	
EW	–.4745	3.54	EW.YBSH	–.1612	
SH	–.6390	5.51	SH.YBEW	–.5380	4.04
SW	–.3946	2.85	SW.YBEH	–.2354	
HW	.2100		HW.YBES	–.3212	2.14

Multiple correlation $R_{Y\cdot BESHW} = .8321$

weaker appearing straw. This causes the correlation $r_{YS} = —.5799$ which is reduced to $r_{YS\cdot BEHW} = .1637$ when the other variables are held constant.

Considering yield and earliness; in the H–44–24 × Marquis strains the partial and zero order coefficients are quite significant and very close to the same value. In this case it would appear to be a genetic relationship although further investigation of this point would be desirable. In the Marquillo strains the partial coefficient is much lower than the simple coefficient and this seems to be accounted for partly by the relations between earliness and strength of straw, height, and seed weight.

Among the H–44–24 × Marquis lines the association between awning and the other variables studied was determined by means of contingency tables for which values of χ^2 were calculated. These tables are given together in table 7, with the values of χ^2 and P. The evident relation between yield and the awned condition is very interesting. It is probably a physiological relation as previously pointed out by Hayes (*4*) who obtained similar differences between awned and awnless segregates from wheat crosses. The super-

iority of our awned strains seemed quite evident in the field. They produced plumper grain and appeared to be freer from diseases than the awnless strains. The association with yield however could not be due to a linkage between awns and resistance to black chaff as susceptibility to black chaff and the awned condition came from the same parent, H-44-24.

TABLE 7. *Contingency tables for relations between awning and earliness, height, black chaff, strength of straw, seed weight, and yield, in a group of lines from an H-44-24 × Marquis cross.*

	Earliness—days seeding to heading							χ^2	P
	65-67	68	69	70	71-72	Total	Mean*		
Awned	7	11	9	6	4	37	68.68	10.83	.029
Awnless	5	5	12	11	17	50	69.66		
	Height in inches								
	36-37	38-39	40-41	42-43		Total	Mean		
Awned	5	12	13	6		36	39.56	2.53	.476
Awnless	7	20	19	3		49	39.20		
	Black Chaff—percentage basis								
	6-15	16-25	26-40			Total	Mean		
Awned	9	24	4			37	18.44	6.54	.039
Awnless	3	37	10			50	21.90		
	Strength of straw—percentage basis								
	36-70	71-80	81-90			Total	Mean		
Awned	6	25	5			36	74.58	2.95	.230
Awnless	3	33	11			47	76.65		
	Seed weight—weight of 500 kernels								
	12.5-13.5	13.5-14.5	14.5-15.5	15.5-17.5		Total	Mean		
Awned	4	12	15	6		37	14.66	1.52	.682
Awnless	7	19	14	10		50	14.69		
	Yield—average yield in grams								
	151-200	201-250	251-325			Total	Mean		
Awned	6	7	21			34	245.6	15.87	.0004
Awnless	18	21	9			48	215.6		

*Means calculated from finer groupings.

SUMMARY

1. It is pointed out that Dr. Fisher's analysis of variance may be used to measure the significance of varietal differences.

2. The analysis of variance is discussed and the method of calculation demonstrated using yield data from the 1926 rod rows for 156 varieties and strains.

3. The analysis of variance was applied to data from rod rows of wheat grown at the Dominion Rust Research Laboratory in 1925, 1926, and 1928, considering the characters, yield, earliness, strength of straw, height, seed weight, susceptibility to stem rust, susceptibility to leaf rust, and susceptibility to black chaff. The 1928 rod rows consisted chiefly of a group of Marquillo lines and a group of hybrid lines from an H–44–24 × Marquis cross which were uniformly resistant to black stem rust. The differences for susceptibility to black chaff in both groups of strains were found to be quite significant and this is considered a very important result especially with reference to the hybrid lines as it indicates incompleteness of the linkage between resistance to stem rust and susceptibility to black chaff.

4. For the two groups of lines zero order and partial correlation coefficients were calculated for all possible pairs of the variables, yield, earliness, height, strength of straw, seed weight, and black chaff. In both cases significant negative correlations were obtained for yield and black chaff.

5. In the H–44–24 × Marquis strains it was found that the awned strains gave significantly higher yields than the awnless ones.

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